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Nations struggling toward international treaty on global warming Page 13

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CHEMICAL & ENGINEERING NEWS

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MARCH 5, 1990

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■ **Industry assesses economic impact of clean air bills, says enactment will cause loss of at least 200,000 jobs.** **Page 6**

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Cover: Contour farming in Lancaster County, Pennsylvania. Photo by Larry Lefever, Grant Heilman Photography Inc.

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Science/Technology

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LETTERS

Disposing of paints

SIR: Marc Reisch's product report, "Demand Puts Paint Sales at Record Levels" (C&EN, Oct. 30, 19 , page 29), does a thorough job of c ering market and new product trend in the paint industry. Unfortunately, it failed to address an increasingly important issue confronting paint manufacturers and users: proper disposal of used paints by retail-level consumers.

Paints pose the greatest difficulty, in terms of both quantity and expense, of any category of materials submitted by small-volume users (e.g., homeowners, small businesses) to local hazardous material collection and disposal programs. Informal surveys suggest that most paints are disposed of in environmentally unsound fashion by users who do not participate in such programs.

It is clear that some sort of action to increase compliance with safe disposal practices is needed soon. Among options being considered to cover the costs of suitable disposal and user education is a state tax applied to manufacturers who sell in Michigan. It is hoped that the paint industry, users, and C&EN readers will become aware of this concern as they develop, market, and use new products.

Dean W. Knuth
Kalamazoo, Mich.

Patent profitability

SIR: I have been a member of ACS for more than 50 years, and this is my first letter to the editor of C&EN. But a letter from William S. Lovell (C&EN, Aug. 14, 1989, page 3) compels me to reply.

I read his letter regarding patents and found it of interest as well as correct in a number of the points that he made in the course of his discourse. However, I feel that he is absolutely incorrect in one statement that he made as to the value of patents.

Lovell made the unqualified statement, "No patent, unless it has been licensed, has ever made anyone a dime (except, of course, for patent attorneys and the patent office)." Nothing could be further from the truth.

Most patents provide their greatest financial return to the patentee or owner in the higher degree of profit derived from the fact that the patent (assuming it is a good, protective one) allows the owner to get a higher price for his patented product than he would otherwise receive if the product was unpatented and open to cut-throat competition.

Some years ago I was chief patent counsel for a Fortune-500 company and had reason to do a comprehensive patent study covering all divisions of the company. The data provided by the study clearly showed that there was a direct correlation between the percentage of the products sold by a division that were covered by patents and the level of profit made by that division. In other words, the higher the percentage of patented products to total products sold, the greater the level of profit made by the division.

Also, when a company purchases another company having a substantial patent portfolio, the patents constitute an intangible asset that depreciates in value over the life of the patents, and can be used as a tax-deductible amount by the acquiring company in its corporate income taxes.

There are innumerable other ways in which valid patents can be of financial benefit to their patentee or the assignee owner.

Karl W. Brownell
Patent Counsel
Lewiston, N.Y.

Qualified Ph.D. candidates

SIR: Janice Long's article on alarms raised on the pending Ph.D. shortage (C&EN, Jan. 29, page 6) is reminiscent of similar concerns raised in the early 1970s and 1980s. As vice president of Epolin Inc., a small chemical firm, each week we receive dozens of unsolicited résumés from individuals who are either underemployed or unemployed—most of whom have exceptional qualifications. I would be pleased to offer our services and furnish these résumés, at no charge, to those companies and universities who claim not to be able to obtain quality candidates. Would any reader like to place a small wager on the number of replies I will obtain!

We are all aware of the large number of chemists and engineers that have lost their jobs during the past few years, many of whom have years of experience and could make a real contribution to science, but cannot find employment. This is the real national tragedy!

I would also like to hear from those universities that cannot find individuals to replace retiring faculty members. As an adjunct professor, I am personally aware of receiving in excess of 100 responses to a single advertised position. In a nutshell, there is no shortage, there never was, and I doubt that there will be into the 2000s.

International Negotiations Inching Toward Global Climate Treaty

Bush has been wary of radical changes in U.S. policy but other nations want action, and negotiations are set to begin in fall, whatever the U.S. role

Pamela S. Zurer, C&EN Washington

While U.S. policymakers hesitate to call for direct action to stem the accumulation of greenhouse gases like carbon dioxide in the atmosphere, other nations are pressing for concrete steps to avert global warming. Formal negotiations heading toward an international treaty on climate change are set to begin this fall—regardless of whether the U.S. takes a forceful role.

Despite promising when he was a Presidential candidate to fight the greenhouse effect with "the White House effect," President Bush has so far been wary of any radical alterations in U.S. policy. He and his chief of staff, John H. Sununu, believe that the scientific uncertainties surrounding global warming are too great to justify policies that would require changes in, say, fossil fuel use at costs that currently are difficult to quantify.

Instead, they stress strategies that make sense in and of themselves—such as increasing energy efficiency, banning chlorofluorocarbons (CFCs) that not only are greenhouse gases but also deplete the ozone layer, and reforestation.

According to a recent report by the General Accounting Office on the Administration's global warming policy, "Its early approach has been to proceed cautiously and defer specific new commitments until more is known about the validity and consequences of global warming." For example, Bush has refused to commit the U.S. to specific reductions in carbon dioxide emissions. Instead he stresses the need for more research on both scientific and economic issues.

In a speech last month to an international meeting on climate change, Bush once again emphasized the need for more knowledge before action. "Where politics and opinion have outpaced the science, we are accelerating our support of the technology to bridge that gap," he said.

Bush received a lukewarm response from his audience, the International Panel on Climate Change (IPCC). Set up in 1988 by the World Meteorological Organization and the United Nations Environment Program (UNEP), IPCC is charged with preparing a comprehensive report on the issue.

Delegates from 59 nations gathered in February in Washington, D.C., to review the progress of IPCC's three working groups. The U.S. chairs the response strategies working group; the U.K. heads the group responsible for reviewing and assessing the science relevant to climate change; and the U.S.S.R. chairs the group assessing the possible environmental and socioeconomic impacts of such change.

The response strategies being studied range from public education to technology transfer to legal measures—including a treaty on climate change. The UN General Assembly voted last year to start negotiations on such a treaty as soon as IPCC completes its report in August. And the Bush Administration has continually asserted that unilateral actions by the U.S. before the IPCC finishes its work would be counterproductive.

Climate change negotiations prompt plethora of meetings

February 1979	1st World Climate Conference; Geneva
October 1985	International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts; Villach, Austria
June 1988	Conference on the Changing Atmosphere; Toronto
November 1988	1st Plenary Session, Intergovernmental Panel on Climate Change (IPCC); Geneva
June 1989	2nd Plenary Session, IPCC; Nairobi
September 1989	Conference on the Global Environment and Human Response Toward Sustainable Development; Tokyo
November 1989	Ministerial Conference on Atmospheric and Climatic Change; Noordwijk, the Netherlands
December 1989	World Conference on Preparing for Climate Change; Cairo
February 1990	3rd Plenary Session, IPCC; Washington, D.C.
August 1990	4th Plenary Session, IPCC, scheduled; Sundsvall, Sweden
November 1990	2nd World Climate Convention scheduled; Geneva
June 1992	UN Conference on Environment and Development, proposed

Note: Meetings sponsored by United Nations agencies are printed in color.

IPCC's chairman, Bert Bolin, professor of meteorology at the University of Stockholm, stressed at the meeting that IPCC's function was to gather and assess information, not to recommend any specific policies for dealing with global warming. "It's not for us to express the political desirability or feasibility of how that will be done," he said. "But good data make it possible for nations to act."

Nevertheless, many of the delegates seemed bemused at best and more often annoyed by the persistent U.S. focus on the uncertainties in the science of global warming to the neglect of areas of agreement. For example, recent computer studies that show clouds might moderate global warming have received a lot of attention in the U.S. from some who would argue climate change is nothing to worry about.

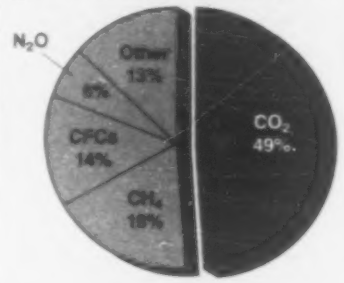
U.K. delegate Geoff Jenkins, speaking for the head of the science working group, referred to the debate about the cloud studies as "a domestic [U.S.] political dispute." Even including the newest cloud models, he said, the working group's assessment of the amount average global temperature will rise still ranges between 1.5 and 4.5 °C. That's the spread that has been generally accepted for about five years.

"Depending on the characterization of clouds in models," Jenkins said, "we can get different answers as to the effective temperature rise when you double the amount of carbon dioxide. But it would be unfair to say that the new results, which have lesser warming, are any more credible than the older results."

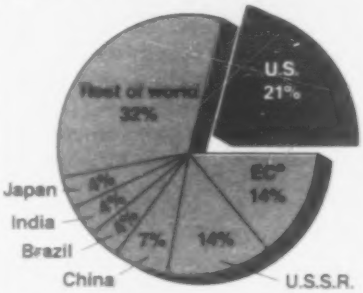
A similar point was made by Bolin in his remarks to the IPCC's opening session. "I am wondering sometimes why those that consider the projections to be overestimates of future changes are considered more 'sensible' by many politicians than those that worry about the upper part of the scientifically established uncertainty range," he said.

Bolin also said there is now a general awareness among nations about the threat of climate change and that the politics of the issue is entering a new phase. Countries are turning their attention, he said, to figuring out what to do to prevent and adapt to global warming—and what their positions should be in upcoming negotiations.

CO_2 contributes most to greenhouse warming . . .



. . . and U.S. emits the most greenhouse gases



Note: Estimated contributions calculated from atmospheric concentrations and radiative properties of gases. a European Community.
Source: Environmental Protection Agency

Many difficult questions will have to be hammered out if a meaningful framework convention—that is, international agreement or treaty—on climate change is to be achieved. Peter Usher, program manager of UNEP's environmental assessment project, says UNEP is preparing for negotiations to start in earnest this fall after the IPCC's report is presented to the 2nd World Climate Conference in November.

"How long it will take to complete negotiations, of course, depends on the type of agreement you are trying to reach," he says. "It must be acceptable to the greatest number of countries but at the same time be useful."

The negotiations that led to the Montreal Protocol on Substances That Deplete the Ozone Layer, which limits production of CFCs, are often proposed as a model for reaching an agreement on climate. The Montreal protocol, agreed to in 1987, is actually an attachment to a more general agreement called the Vienna Convention.

That agreement, completed in 1985, simply states that the nations of the world should protect the ozone layer. The specifics of how to do so were thrashed out separately, and with much greater difficulty, in the Montreal protocol negotiations. The road to a climate treaty might follow the same path: First a basic convention stating that global climate is worth protecting, followed by more exacting protocols spelling out how to do it.

But many nations, and UNEP itself, want a climate treaty with more teeth in it from the start. "The Vienna Convention is rather vague," says Usher. "We've grown up a little since then and we feel in UNEP there should be some specific obligations within the climate convention."

The requirements that UNEP would like in an initial treaty include the same "no regrets" strategies the Bush Administration advocates: energy conservation and reforestation. Targets for cutting emissions of greenhouse gases, while desirable, will be much harder to achieve, Usher says. "It obviously depends on the mood of countries at the time of the negotiations," he says. "Really specific obligations would be in separate protocols."

The climate treaty negotiations will face even more obstacles than did the Montreal protocol because every country has a stake in the outcome. "Developing countries did not play a significant role in the CFC issue; they are not big users," notes Alan Miller, executive director of the University of Maryland's center for global change.

In contrast, China is already the largest coal-consuming country. And Brazil is intimately involved because of its vast tropical forests that are rapidly being cleared. Such deforestation removes a sink for carbon dioxide. The Eastern bloc countries also were not big players in the CFC negotiations, but are a large source of carbon dioxide. "Any effective agreement this time will have to involve very diverse interests," Miller says.

Some industrialized countries are already formulating their own na-

tional policies on reducing greenhouse gas emissions. Led by the Nordic countries and some members of the European Community, they are following a faster track parallel to the UN-sponsored IPCC process.

Those countries' more aggressive stances were highly visible last November at a meeting of environmental ministers convened by the Dutch government. Most of the 67 countries participating supported a proposal to reduce carbon dioxide emissions 20% by 2000—a proposition that was blocked by the U.S., U.S.S.R., and Japan. The meeting eventually agreed to a nonbinding declaration that acknowledges that greenhouse-gas emissions should be stabilized as soon as possible, but sets no emissions targets or timetable.

One of the most activist countries, Sweden, has already enacted legislation to freeze its carbon dioxide emissions at 1989 levels. That difficult task is made even more complicated by the Swedish government's 1980 decision to eliminate all nuclear power plants by 2010.

The Swedish parliament has been studying how to achieve the carbon dioxide freeze. One proposal being considered very seriously is a carbon tax—that is, fuels would be taxed based on the amount of carbon dioxide produced per unit of energy. In such a scheme, coal would be taxed more heavily than oil, which in turn would bear higher taxes than natural gas.

"If the ... proposals are implemented, Sweden will be the first country in the world to introduce a charge on carbon dioxide," says Maria Garding, a fuels specialist with Sweden's Ministry of Environment & Energy.

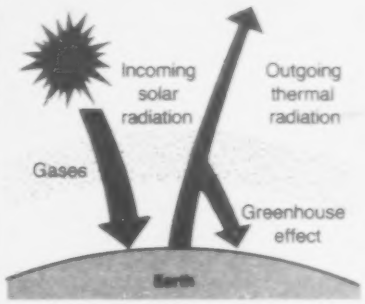
Carbon taxes are an example of the sort of economic incentives that could be used to encourage changes in fossil-fuel use. But greenhouse gases spring from a multitude of sources and controlling them all will be difficult.

Under certain schemes being discussed, however, not every country would have to control every greenhouse gas. The IPCC response strategies working group is studying the idea of emissions trading and the concept of carbon-dioxide equivalence.

Such ideas could benefit countries like Japan, for example, which has already reduced its fossil-fuel use significantly through new technology and energy conservation. If a climate treaty were simply to require, say, every signatory to cut carbon dioxide emissions 10%, it would be much more difficult and expensive for Japan to meet that goal than other industrialized countries that have not already made the easiest changes. Under more flexible schemes, Japan might be able to reduce methane emissions from rice paddies or pipeline leakage by an amount equivalent to a 10% carbon dioxide cut.

These sorts of nitty-gritty questions of how—as well as the sticky question of how much—to reduce emissions of greenhouse gases will be the grist for climate-treaty negotiators in the next few years. □

Greenhouse gases trap heat at Earth's surface



Scientists agree that:

- Certain gases are transparent to incoming solar radiation but absorb outgoing infrared radiation.
- Atmospheric concentration of carbon dioxide, methane, chlorofluorocarbons, nitrous oxide, and other greenhouse gases are increasing.
- As greenhouse gas concentrations increase, so will average global temperature.

Scientists have not reached a consensus on:

- Timing and severity of global warming.
- Regional distribution of impacts of climate change.
- Magnitude of feedback processes.

AAAS probes penalty for scientific fraud

"I do not think that it is a bad thing for persons who intentionally fabricate research data, and lie about their research data, to be told in no uncertain terms that this is wrong, not just in terms of some scientific ideal, but rather criminally wrong. It is fraud, just like embezzling money."

This sentiment, expressed by Harold Edgar of Columbia University, was the focus of considerable discussion at a symposium on misconduct in science and the criminal law at the annual meeting of the American Association for the Advancement of Science in New Orleans last month. Edgar is professor of law, science and technology, at Columbia's law school.

Although Edgar's line of thinking raises the specter of the heavy-handed involvement of criminal prosecutors in the practice of science, he received some support for his contention that scientists who commit fraud should be severely punished. For instance, *Science* editor Daniel E. Koshland Jr. stated that the very few scientists who do commit fraud should face very heavy penalties.

The Columbia lawyer explained that under Title 18 of the United States Code, Section 1001, two aspects of scientific misconduct—the intentional misreporting of research results and the intentional fabricating of research data—plainly constitute crimes when the person involved submits such falsehoods to the U.S. government in seeking, or reporting on, research grants. Plagiarism may, under certain circumstances, also be deemed criminal under this statute.

Although Edgar thinks the criminal prosecution of scientists who commit fraud may become more frequent, he also believes this will have several potential advantages for the science community.

First, in Edgar's view, there is far less chance that the criminal law will reach out to set norms for the practice of science in general than will the "administrative bureaucracy." Second, he believes that

Alternative Agriculture

Bette Hileman
C&EN Washington

During the past year, alternative agriculture has suddenly become topical. Farmers practicing alternative agriculture are still a small minority in the overall farm community. But their farming methods, which among other things are aimed at improving profits, limiting dependence on agricultural chemicals, and increasing use of environmentally friendly procedures, are attracting more attention and a growing number of adherents. Hard data on the productivity of alternative farming compared with conventional techniques are still sketchy at best, although many practitioners seem to be operating quite successfully. And in their success lies the potential for significant impact on markets for fertilizers and pesticides.

When the National Research Council (NRC) published its report "Alternative Agriculture" last September, stories appeared on the front pages of newspapers across the country. Within an hour of the report's release, Charles E. Hess, the Department of Agriculture's (USDA's) assistant secretary of science and education, called it "of unparalleled significance."

And within a few months, a number of groups began condemning it. Dean R. Kleckner, president of the American Farm Bureau Federation, said it is being considered in Washington, D.C., "the new bible" of farming despite a lack of research on its tenets. Resources for the Future, a natural resources research group, called a news conference to argue that the NRC report had given an inaccurate and too optimistic view of both the environmental and economic benefits of alternative agriculture. The Potash & Phosphate Institute in Atlanta, Ga., wrote a lengthy criticism of it, saying it is biased and unscientific. Now, the NRC committee that wrote the report is preparing a response to its critics that will be released in a few weeks.

The major conclusion of the September NRC report is: "A small number of farmers in most sectors of U.S. agriculture currently use alternative farming systems, although components of alternative systems are used more widely. Farmers successfully adopting these systems generally derive significant sustained economic and environmental benefits. Wider adoption of proven alternative systems would result in even greater economic benefits to farmers and environmental gains for the nation." The report also says that the "scientific knowledge, technology, and management skills necessary for widespread adoption of alternative agriculture are not widely available or well defined."

There is a broad range of opinions about the NRC report and the movement toward alternative agriculture in general. But, in the past few months, thoughts about the subject have tended to polarize around two extremes: Proponents argue alternative methods must be adopted quickly to avert environmental catastrophe, whereas critics contend reduced pesticide and fertilizer use, encouraged by alternative farming methods, will lead to a loss in U.S. agricultural productivity and economic competitiveness and are, in any event, not justified by environmental or public health hazards. Farmers and legislators are caught in the middle of the debate, confused by claims and predictions of dire consequences coming from opposing sides.

Probably neither of these extreme views is realistic. Agricultural systems are quite resilient; soil and water resources can overcome many environmental insults. Catastrophies, if they come at all, are likely to happen after decades or centuries, not years. And farmers are

C&EN staff photo

by nature conservative. They tend to adopt new methods slowly and to abandon them quickly if they lead to a loss in productivity.

Although difficult to define precisely, alternative agriculture is a systems approach to farming that seeks to develop a multiyear practice that takes advantage of whatever is produced or can be produced on the farm, including naturally occurring beneficial biological interactions, to ensure soil fertility and to keep losses from pests, weeds, and animal diseases within acceptable levels. The aims are adequate productivity and profitability, conservation of resources, protection of the environment, and assured food safety.

A variety of means are used to achieve these ends, including expanded crop rotations and use of biological pest controls, soil and water conservation practices, and diversification in crops and livestock. For the majority of farmers, the reduction in purchased supplies is more an outcome of a shift in production practices than a goal in and of itself. No one practice or defined set of practices makes a farm alternative.

The vanguard of alternative agriculture in the 1980s has been farmers driven by economic necessity to cut production costs. Farmers who have designed new ways to raise crops and livestock that reduce purchased inputs by using them more efficiently and thereby protect the environment, are probably involved in alternative agriculture. Farmers aiming for profit alone by simply buying whatever seeds, fertilizers, and pesticides seem likely to produce the greatest yields, probably are not involved in alternative agriculture, though they could be using some of the same methods used in alternative agriculture. What sets alternative agriculture apart from conventional is the approach, not the specific methods.

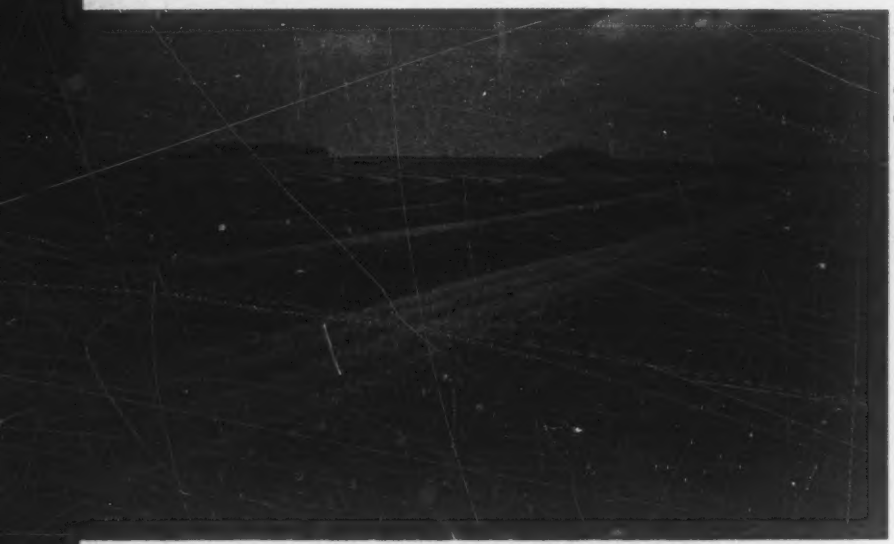
Many critics say alternative agriculture is simply a return to the past. It is not. Though farmers involved in alternative agriculture have resurrected some methods from the past, what they are aiming to do is create a sustainable system using whatever means are available, both old and new, to reach their goals. Most of them are experimenting with new methods continually.

A number of different terms are used interchangeably to connote alternative agriculture—sustainable, low-input, ecological, and regenerative—but they basically refer to the same set of concepts. And when examples of alternative (or low-input) farms are mentioned they tend to be the same farms.

Alternative farms

Even though some critics may disparage alternative agriculture by saying that nearly all modern farmers practice it, most farmers who are using alternative methods contend they are definitely not involved in conventional farming. The majority have changed their methods in just the past few years. They frequently think of themselves as isolated—they are usually one of just a few farms in their townships or counties using these techniques. Many have formed groups—the Practical Farmers of Iowa or the Illinois Sustainable Agriculture Society, for example—to share ideas, learn from each other, and relieve the loneliness of belonging to a small, but growing, minority.

Even the superficial appearance of farms that use alternative methods often differs markedly from that of other farms. For example, one of the best-known farms using alternative methods, Rhichard Thompson's in central Iowa near Ames, is the only one in the neighborhood that has livestock. Suddenly, in a dead-looking winter landscape of snow-covered fields broken only



Tom Frantzen photo

Narrow rows of corn, soybeans, and oats, planted on ridges, follow the land's contours, helping to prevent erosion on this Iowa farm

by an occasional house and collection of farm buildings, cows can be seen ambling on Thompson's fields—even when the temperature is -10 °F. Young pigs bursting out of small heated houses into outdoor pens, each made for only a few pigs, are an unusual sight in a state where most pigs are produced in close confinement in expensive buildings housing 100 or more animals.

Tom Frantzen's farm in Iowa also looks different. Instead of fields planted uniformly with just corn or soybeans, strips only four rows wide, each planted with an alternating crop, wend their way across the land. And in contrast to most of the neighboring farms, which are rather devoid of wildlife, Delmar Akerlund's farm near Valley, Neb., has an abundance of earthworms, songbirds, and other wildlife. The earthworms are so plentiful that during a rainstorm they emerge from the soil and cover the roads adjacent to Akerlund's fields.

No reliable estimates have been made of the numbers of farmers using alternative methods. There is general agreement, however, that the movement is growing. One indication is that the membership of groups of farmers, such as the Nebraska Sustainable Agriculture Society, that practice alternative agriculture, is increasing each year, though each of them still has only a few hundred members.

In any event, farmers involved in alternative agriculture are gaining recognition in the agricultural policy community. Funds for research and extension programs in alternative methods have been appropriated by state legislatures in Illinois, Indiana, Minnesota, Iowa, Wisconsin, Texas, and California. Legislative provisions to enable more farmers to use alternative methods will be discussed this year when Congress debates the 1990 farm bill. USDA's Low Input Sustainable Agriculture program, funded at $4.5 million out of the department's $600 million research budget, is admittedly a small part of USDA's budget programs. But it is attracting a great deal of attention.

Certified Organic Farmers, a trade group, has been deluged with phone calls recently from farmers wanting to learn about organic methods. Several large fruit and vegetable growers in Kern County, California, stunned their competitors last year with a sudden decision to use organic techniques on part of their acreage. A spokesman from Certified Organic Farmers estimates that sales of organic produce doubled to $1 billion in 1988 from 1983.

Several factors occurring during the 1980s have pushed alternative agriculture to the forefront of public debate. First, farmers themselves became interested in it for a variety of reasons, including rising costs of purchased pesticides and fertilizers and growing concerns about the contamination of surface water and groundwater with pesticides and nitrogen fertilizers. Many of the farmers who have tried alternative methods have been very successful at them. The results have been clearly evident—rising yields per acre, fewer pesticide applications, and higher profits per unit of production.

In the past decade, the public also has become more aware of environmental and potential health problems associated with conventional farming. They have become concerned that surface and underground water supplies are being polluted with an increasing number of contaminants from agricultural production. They also became increasingly aware of pesticide residues in food. In February last year, this concern reached a high point with the publicity about a growth regulator, Alar, on apples and in apple products. In early 1990, antibiotic residues in milk also reached public consciousness. Alternative methods often markedly reduce the use of pesticides and synthetic fertilizers on crops, and antibiotics in livestock.

Contemporary agricultural problems

The development in the 20th century of the U.S. agricultural industry has been enormously successful from an economic perspective. In 1900, 37 out of 100 people in the U.S. made their living farming. They produced the

Benbrook: soil on much of U.S. cropland is compacted

food and fiber required for themselves and the other 63 out of 100 who made their living in commerce, industry, and other professions. Today only one out of 100 produces the agricultural goods required to support our society and to supply a large export market. This great increase in labor productivity is no accident. It is the result of generations of agricultural researchers, extension agents, industry representatives, government bureaucrats, political leaders, and farmers all working to build an increasingly sophisticated, large-scale agricultural infrastructure.

Wetlands have been drained and dry lands irrigated. Hundreds of insecticides have been developed and billions of pounds produced and dispersed over agricultural fields. Extensive use of herbicides has made weed control possible while conserving the use of tractor fuels in cultivation. Machinery to perform almost every task imaginable has been invented, much of it used in everyday farm operations. An amazing variety of chemicals is available to farmers, and vast tonnages are produced and applied annually. Agricultural researchers have developed improved seeds that require large amounts of fertilizer to obtain high yields. The American agricultural system has become the wonder and envy of much of the rest of the world.

Though modern conventional farming is highly successful in terms of total production and output per hour of human labor, it has troubling shortcomings when evaluated by other standards. Prominent among these are concern for human health and wildlife, the long-term sustainability of the resources that agriculture itself depends on, and the social and economic structures and viability of rural communities.

Even though 225,000 tons of pesticides are used annually on crops in the U.S., much of the crop yield is lost to pests, diseases, and weeds. According to David Pimentel, ecologist and entomologist at Cornell University, although the use of synthetic pesticides has shown a 33-fold increase since 1945, crop losses from insects, diseases, and weeds have increased from 31% in 1945 to 37% today.

In its 1989 report on alternative agriculture, NRC approaches the issue somewhat differently. Pesticides "have helped maintain pest damage at between 5 and 30% of potential production in many cropping situations, including highly uniform and often continuous monocultures that would otherwise be highly susceptible to severe pest damage," it states.

The interactions between farm management and pest pressure underlie the difficulty of assessing losses from pests. Establishing even a baseline for potential crop loss under various control methods depends on how the issue is approached. For example, corn grown continuously in the same field year after year is very susceptible to corn rootworm and therefore generally must be treated with insecticide incorporated in the soil, but if corn is grown in almost any type of rotation, corn rootworm is rarely a problem. It is hard to say whether insecticides for corn rootworm save a percentage of the crop, or simply allow corn to be grown as a continuous monoculture, as more than 30% of it is today.

As a result of efforts to control insects with insecticides, about 440 different insect and mite species and 70 fungus species have become resistant to some pesticides. Higher doses of the same pesticides or combinations of pesticides or substitution of different pesticides are necessary to control these resistant species. Also, broad-spectrum insecticides often kill the natural enemies of insect pests, thereby disrupting, rather than conserving, field ecosystems and allowing previously innocuous species to cause major crop damage.

Weed resistance, at first not believed to exist with herbicides, is also a problem. By 1989, about 80 out of a total of more than 500 weed species were found to be resistant to herbicides. Herbicides not only create resistance, they alter the mix of weeds that typically occur in an area. In Iowa, for instance, as some grassy weeds have been knocked out by herbicides, other kinds of broadleaf weeds, like velvetleaf, that are more difficult to control have come in to take their place.

About 20 years ago, shortly after herbicides were introduced, they nearly eliminated the need to cultivate for weeds. Now, because of weed resistance, farmers who use herbicides must still cultivate, though usually not as much so they would without them, says I. Garth Youngberg, executive director of the Institute for Alternative Agriculture.

Certain persistent herbicides used on some crops also make it impossible or difficult to grow certain other crops the next year. For example, if a farmer uses a persistent herbicide on a plot of land, he or she may not be able to get a good hay yield on that land the next year. Unfortunately, herbicide carryover and the development of genetic resistance are special problems with some of the highly effective, environmentally benign, low-dose sulfonylurea herbicides introduced in the past five years.

Pesticide contamination of both ground and surface waters from agricultural use has become increasingly prevalent in recent years. Some pesticides do not degrade very quickly and percolate through soils, especially sandy soils, into groundwater. Pesticides also can be carried attached to eroding soil particles and contaminate lakes, rivers, and estuaries.

In 1988, the Environmental Protection Agency (EPA) in a very incomplete survey detected 46 pesticides that could be attributed to normal agricultural use in the groundwater of 26 states. Most were detected below the health advisory level set by EPA, but nine were found at higher levels. The compounds found most frequently in groundwater were atrazine and aldicarb—the most acutely toxic registered pesticide. (Only 0.9 mg per kg body weight kills 50% of the test animals exposed to aldicarb.)

Another problem is that of pesticide residues on some foods. Even though the levels detected are very low, they have raised concern because herbicides accounting for 50%, fungicides accounting for 90%, and insecticides accounting for 30% of all agricultural use have been found to cause cancer in laboratory animals.

According to NRC, "pesticide residues in the average diet do not make a major contribution to the overall risk of cancer for humans," but the risk from pesticides "may not be insignificant." Fungicides are of particular

Groundwater of more than half the states contains pesticides from agricultural use

Pesticide	Health advisory level[a] (ppb)	States	Median concentration[b] (ppb)
Alachlor	1.5[c]	Connecticut, Florida, Illinois, Iowa, Kansas, Louisiana, Massachusetts, Maine, Nebraska, Pennsylvania, Wisconsin	0.90
Aldicarb	10	California, Florida, Massachusetts, North Carolina, New York, Rhode Island, Wisconsin	9.00
Atrazine	3.0	California, Colorado, Connecticut, Illinois, Iowa, Kansas, Maryland, Maine, Nebraska, New Jersey, Pennsylvania, Vermont, Wisconsin	0.50
Bromacil	80	California, Florida	9.00
Carbofuran	36	Massachusetts, New York, Rhode Island	5.30
Chlordane	0.03[c]	Mississippi	1.70
Chlorothalonil	1.5[c]	Maine, New York	0.02
Cyanazine	9.0	Iowa, Louisiana, Maryland, Nebraska, Pennsylvania, Vermont	0.40
1,2-D	0.0013[c]	California, Connecticut, Massachusetts, New York	4.50
1,3-D	0.20[c]	New York	123.00
2,4-D	70	Connecticut, Mississippi	1.40
DCPA	3500	New York	109.00
Diazinon	0.63	Mississippi	162.00
Dibromochloropropane	0.02	Arizona, California	0.61
Dicamba	9.0	Connecticut, Maine	0.60
Dieldrin	0.00219[c]	Nebraska, New Jersey	0.02
Dinoseb	7.0	Massachusetts, Maine, New York	0.70
Diuron	14	California	na
Ethylene dibromide	0.0005[c]	California, Connecticut, Georgia, Massachusetts, New York, Washington	0.90
Fonofos	14	Iowa, Nebraska	0.10
Hexazinone	210	Maine	8.00
Lindane	0.026[c]	Mississippi, New Jersey, South Carolina	0.10
Methyl parathion	2.0	Mississippi	88.40
Metolachlor	10	Connecticut, Illinois, Iowa, Pennsylvania, Wisconsin	0.40
Metribuzin	175	Illinois, Iowa, Kansas, Wisconsin	0.60
Oxamyl	175	Massachusetts, New York, Rhode Island	4.30
Picloram	490	Maine, North Dakota, Wisconsin	1.40
Prometon	100	Texas	16.60
Propazine	14	Nebraska, Pennsylvania	0.20
Simazine	35	California, Connecticut, Maryland, Nebraska, New Jersey, Pennsylvania, Vermont	0.30
TDE	0.031	Mississippi	4.80
Trifluralin	2.0	Kansas, Maryland, Mississippi, Nebraska	0.40

a Lifetime health advisory level proposed by Environmental Protection Agency. b Median of the concentration of positive detections for all confirmed studies. If multiple studies were not done on a particular chemical, the single-study average is given. c Carcinogen. EPA proposed lifetime healthy advisory level is based on the exposure levels that present a one in a million risk of cancer in the exposed population. na = not available. Source: Environmental Protection Agency

concern because they are used in combinations and "few effective alternatives are available or under development." NRC points out that synergistic effects may result from residues of more than one pesticide.

However, a new study carried out by Fermenta ASC found that residues of the fungicide chlorothalonil were reduced considerably as celery, cabbage, tomatoes, and cucumbers moved from farm to table. In some of these vegetables, washing, grading, trimming, packaging, and cooling lowered residue levels by more than a factor of 10.

Some pesticides seem to pose a health threat for farmers who use them frequently. The National Cancer Institute found in a study of farm workers that those who are exposed to herbicides for more than 20 days each year are six times more likely than the average person to develop non-Hodgkin's lymphoma. In a followup study, NCI found a threefold increase in risk for the same disease in farm workers who used 2,4-dichlorophenoxy acetic acid (2,4-D) more than 20 days per year.

Pesticide use has also stressed wildlife populations and decimated large wild and domestic honeybee populations. Bees are important for farmers because they are necessary for pollinating about $20 billion worth of fruits, vegetables, and forage crops.

Agriculture is the largest diffuse source of water pollution in most states. Large amounts of nutrients applied as fertilizer are absolutely essential to the productivity of U.S. agriculture. But the major pollutant from farmland in most cropping regions is fertilizer runoff.

Nutrients have several different types of adverse environmental impacts. First, nitrate from all sources—synthetic fertilizers, manure, and green manures (legumes)—is soluble in rainwater and, if not used by plants, leaches through the soil to contaminate groundwater or surface water. There is evidence that nitrate contamination of groundwater supplies is increasing. A U.S. Geological Survey study found nitrate levels in 87 of 1663 counties above 10 mg per L—EPA's interim standard for nitrate in drinking water. Extensive exposure to nitrate levels above 10 mg per L can lead to methemoglobinemia (oxygen deficiency in the blood), particularly in nursing infants and in the elderly.

Unlike nitrate, excess phosphorus from fertilizer is not very soluble, but it is carried on eroding soil particles to streams, lakes, and estuaries. Both nitrate and phosphorus, but especially phosphorus, promote abundant growth of algae, which, when it dies, decays on the bottom of water bodies, depleting the oxygen in the water. As a result, dissolved oxygen is less available for higher order aquatic plants and animals.

There is a great deal of evidence that nitrogen fertilizers are being overapplied. Alfred M. Blackmer, agronomist at Iowa State University, says that probably more than half of the nitrogen put on the soils in the corn belt is not taken up by crops. "It is likely that a substantial portion of this nitrogen finds its way into groundwater supplies," he says.

In regions of the country where livestock production results in the need for disposal of large volumes of manure on agricultural fields, the situation is aggravated still further by farmers' common practice of applying synthetic fertilizers at the same rate that would be required without manure, says Charles M. Benbrook, executive director of NRC's Board on Agriculture. In some midwestern cropping-livestock areas, researchers have found fields with more than 10 times the level of available nitrogen needed to support maximum yields.

Phosphorus fertilizer is also being overused as is pointed out in the NRC report. "Most state soil test labs report that the number of farm fields testing high or very high in phosphorus increased dramatically from the 1950s to the 1980s," says Raymond R. Weil, agronomist at the University of Maryland. Problems with overuse of fertilizers could be eliminated fairly easily by more precise application methods and with greater use of soil tests.

Erosion depletes topsoil, increasing the need for fertilizer. Eventually erosion makes land totally unproductive. It also causes siltation of streams, lakes, and reservoirs and excessive turbidity in surface waters. This, in turn, blocks out light, resulting in the decline of submerged aquatic vegetation. Because nutrients and some pesticides are carried on soil particles, erosion also contaminates surface waters.

Agricultural specialists differ greatly in their assessments of how serious the erosion problem is in the U.S. Benbrook says erosion is still a serious problem on only about 20 million to 30 million acres of U.S. farmland, out of a total of about 400 million acres, as a result of the effectiveness of erosion control provisions in the 1985 farm bill (the Food Security Act of 1985)—especially the conservation reserve program.

Pimentel's view is less sanguine. Erosion on average is proceeding at 20 times the rate of replenishment, he claims. For example, in Iowa, half the topsoil has been lost in the past 150 years.

Wes Jackson, geneticist and head of the Land Institute in Salina, Kan., a think tank devoted to sustainable agriculture, shares Pimentel's concern. On anything but dead-level cropland, soil losses from erosion are usually too high to be sustainable in the long run, he notes.

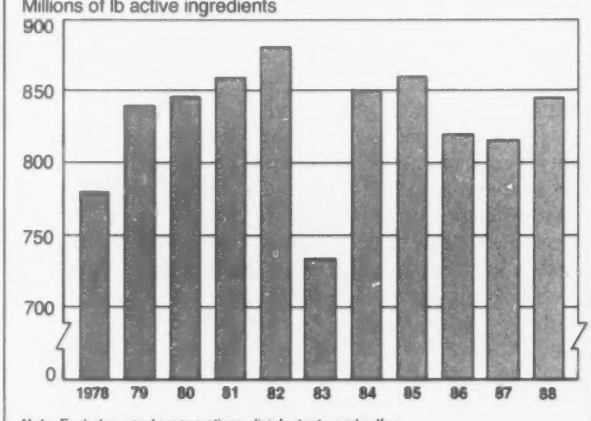
According to Benbrook, on flat, generally richer soils not subject to heavy erosion, compaction is one of the more serious problems that results from conventional farming practices. Soil on much of the nation's cropland—perhaps half the intensively cultivated row-crop and small grain acreage, in Benbrook's view—is becoming, or already is, compacted. As a result, this soil fails to take in and hold precious water as effectively as soils with more tilth. Compaction is caused by growing shallow-rooted crops year after year, by not incorporating enough organic matter into the soil, by practices that alter soil microbial and earthworm populations, and by using heavy machinery, particularly on wet soils. Compacted soil, when dry, looks like brick. It restricts root growth and has soil oxygen levels below those necessary for optimum uptake of nutrients.

Compacted soil can be restored by planting deep-rooted crops, such as alfalfa, incorporating organic materials like green manure and animal wastes, or using a subsoil tiller. But tillage equipment is heavy and requires a great deal of fuel to pull through tightly bound soils. Moreover, subsoil tillage must be timed very carefully. If the soil is too dry or too wet, subsoil tillage merely makes the problem worse.

Probably the most hard-to-solve natural resource problem associated with conventional agriculture is the depletion of aquifers. The Great Plains, which encompass one fifth of the land area of the contiguous 48 states, are running out of water very quickly. The Ogallala aquifer, the main source of irrigation water on the plains, is being pumped out 20 times faster than it is recharging itself, and at the present rate, irrigation from the aquifer can last only a half-century, says Richard Black, an irrigation specialist at Kansas State University. Under parts of the Texas panhandle where the formation is thinner, the aquifer has already become so depleted that many farms have reverted to dryland farming.

Cases of salmonella food poisoning in the U.S. have escalated in recent years. Reported incidence rose from

Agricultural use of pesticides has declined slightly since early 1980s



Note: Excludes wood preservatives, disinfectants, and sulfur.
Source: Environmental Protection Agency

about 3 per 100,000 people in 1955 to 20 per 100,000 in 1987. Some experts believe that a significant part of the increase can be attributed to changes in animal husbandry requiring the use of antibiotics in animal feed. The use of antibiotics, now 9.9 million lb annually, has risen as more and more farm animals are raised confined in large buildings where they live in close proximity to each other. Because animals raised in this way have greater risk of respiratory and other diseases, small amounts of antibiotics are added to their feed. The antibiotics also promote growth.

Last year, the Institute of Medicine at NRC reported that though there is little direct evidence of a link between the subtherapeutic use of antimicrobials in livestock and human disease, there is substantial circumstantial evidence of such a link. Daily use of antibiotics causes resistant salmonella to develop in livestock. Since the same antibiotics are also used in humans, human disease caused by salmonella sometimes resists treatment. The institute conservatively estimated that salmonella from the use of subtherapeutic antimicrobials causes about 40 deaths per year.

A number of economic problems plague modern U.S. agriculture. First, about a quarter of the farms owned by individuals went out of business during the 1980s. Many were caught in a debt squeeze as commodity and land prices fell while prices of fuel, fertilizers, herbicides, and seed rose through 1984.

The number of lost farms would have been even greater if federal farm support programs had not escalated from $3.5 billion in 1978 to a peak of $26 billion in 1986 and remained fairly high, at about $11 billion, in 1989.

Despite the high cost of federal support programs, net farm income including federal payments has risen only slightly in real purchasing power since 1970. And even now, about 19% of all farms are financially shaky. Many operators have taken second jobs, not because they spend less than eight hours a day on the farm, but because that is the only way they can afford to keep their farms.

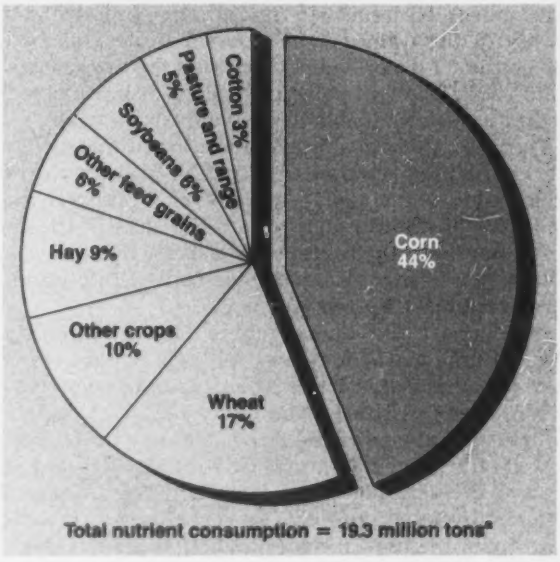
Alternative farming methods

Alternative agriculture originated with farmers who became dissatisfied with the performance of conventional farming systems. Most of them are in New England, the Midwest, California, and Texas, though there are a number in every state.

Some, like Frederick Kirschenmann in North Dakota, found that their soil seemed harder and harder to plow each year and required more and more fertilizer to produce the same yield. Some saw their insect control practices failing despite their increasing use of insecticide. Some simply found they were making little or no money each year because their input costs were going up while their gross sales were remaining steady or declining.

A number of these farmers managed to work out systems that seemed to them more sustainable over the long run and in many cases just as productive. Some of them carried on extensive experiments on their own farms to find alternative systems that worked best.

Corn accounts for nearly half of U.S. fertilizer consumption



a For year ending June 30, 1989. **Sources:** Doane, Department of Agriculture

Many novel ideas were tried and rejected as ineffective or impractical. Eventually though, several farmers who had worked out successful new systems became known to the agricultural research establishment. The establishment—the cooperative extension service at Iowa State University, for example—then began to take notice, participating even in direct research on such farms.

When NRC first began to investigate alternative farming in 1984, many of its committee members were skeptical about the success of these farms, Benbrook recalls. They found it hard to believe that some farms could produce crops well with little or no pesticides or that some could raise animals profitably without subtherapeutic use of antibiotics. They speculated that such farms must have some unusual characteristics—perhaps better soil, lots of available labor, or some other distinct attributes—that enabled them to do things differently.

But when the committee members learned more about the farms, they found that they were typical in most respects, though managed in an unconventional way.

Not enough research has been done on any of the alternative systems that farmers have developed to know whether they are sustainable in the long run. Nor can the systems simply be copied on farms across the U.S. Conditions vary greatly and so must farming systems; further research is clearly needed. However, a number of the methods used are based on accepted scientific principles and a wealth of empirical evidence.

There has not been enough experimentation with alternative systems to discuss them in the aggregate. For example, it is not possible to say: "out of 1000 farms using the new ridge-tillage system, 750 had better yields,"

because research trials have not been done on 1000 farms. As a consequence, specific farms must often be used to illustrate alternative systems, just as case studies are often used in medicine and business administration to indicate, but not prove, the results from certain practices.

One of the most common methods used in alternative farming is increased crop rotations, especially rotations over more than two years. Rotations help control insects and diseases, particularly those that attack roots, by eliminating the food of the disease or pest and thus often preventing destructive levels of pests or disease organisms from becoming established.

For example, damage from wheat root pathogens in Washington state can be greatly decreased with two-year rotations with peas and virtually eliminated with three-year rotations with barley and peas or lentils.

Even when grain follows a nonleguminous crop and therefore does not benefit from nitrogen supplied by a legume, rotations also increase yield for reasons not entirely understood. And grain yields following a legume are usually greater than yields of grain planted as a continuous monoculture, no matter how much fertilizer is applied.

Rotations, especially sod-based ones, add organic material to the soil, increasing its water holding capacity, reducing compaction, and providing food for soil organisms that recycle soil nutrients.

Deep-rooted crops, such as alfalfa, used in rotations bring soil nutrients to the surface and make them available for shallow-rooted crops. They also help prevent soil compaction by forming deep root channels.

Rotations also can help control erosion, especially if hay or forage crops or closely seeded grain crops are planted in strips that follow the contour of the land. Rotations that include crops, such as rye, that are allelopathic to weeds aid in weed control. (Allelopathic plants contain chemicals that suppress growth of other plants.) Some farmers who plant rye one year find that they need little or no herbicide the next year.

Usually, farms with rotations have different fields or different strips planted in a variety of crops. Because a severe insect attack or disease usually attacks only one crop in a given year, crop rotation reduces the likelihood that all the crops will fail. However, rotations that include hay and forages are probably not economical for farms without livestock or a developed hay market.

A number of methods to maintain soil fertility, while at the same time reducing the amount of purchased fertilizer, are being used in alternative farming systems. Some of these techniques are saving farmers substantial amounts of money, even in the first year they are used.

One practice involves the more careful and precise management of the primary plant nutrients. Farmers in Iowa are using a new soil test for nitrogen that gauges the amount the crop needs precisely. Soil tests for potassium and phosphorus and a soil test for nitrogen for semiarid climates have been available for many years. But a test for nitrogen for regions where there is adequate rainfall was developed only recently. Farmers can use a kit and analyze their soil samples themselves in just a few hours. The kit is based on cadmium reduction of nitrate to nitrite and colorimetric determination of nitrite. The test allows farmers to estimate more precisely, when the plants are 6- to 12-inches high, the minimum amount of nitrogen fertilizer needed for maximum yield.

Fifty-eight on-farm trials comparing the conventional fertilizer practice with the new practice involving the soil test have been coordinated by the extension service at Iowa State and by agronomist Blackmer in cooperation with fertilizer dealers. In both sets of trials, the yields on fields with the reduced application of nitrogen recommended by the soil test were the same as the yields on fields where fertilizer was applied in conventional amounts.

Blackmer estimates, over the long run, Iowa farmers who use the new soil test will need about a third less fertilizer than they used in the past. Just in Iowa, "that could mean an annual saving of $100 million at current prices," he says. Similar nitrogen soil tests have been used successfully by farmers in Wisconsin, Vermont, Pennsylvania, and Connecticut.

Triazine herbicides detected in streams in 10 midwestern states

Detectable levels of triazine herbicides exist in more than half the streams in the midwestern U.S., according to a new U.S. Geological Survey (USGS) study.

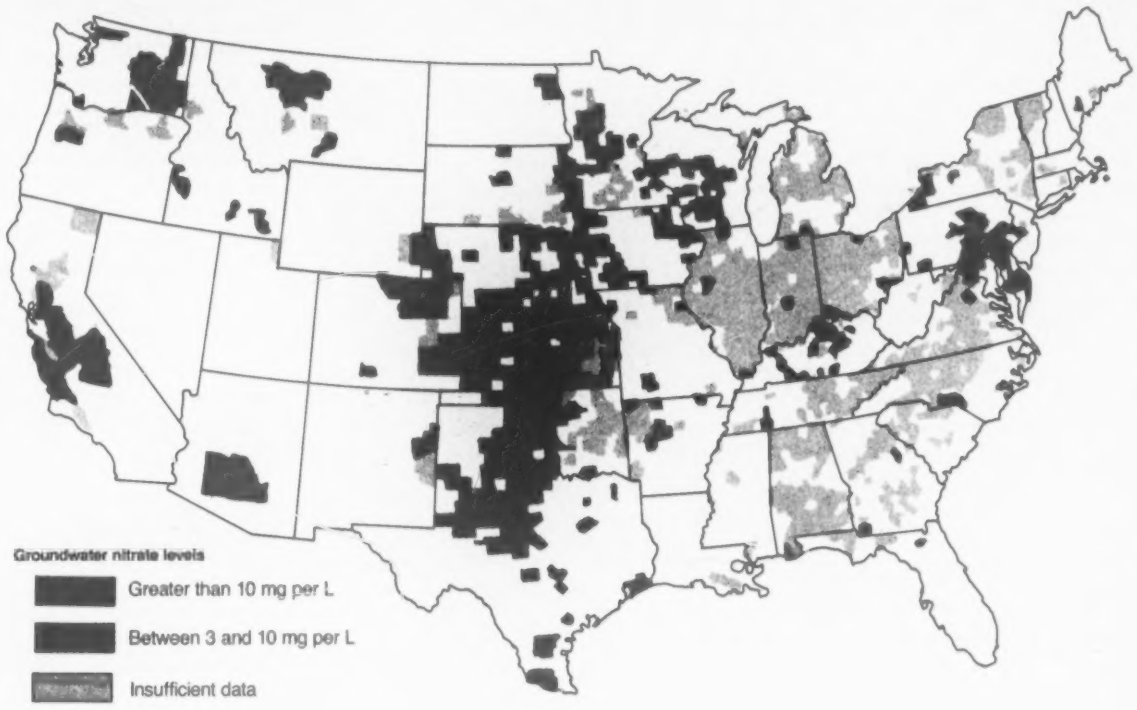
Last year, in the early spring before herbicides were sprayed on the fields, USGS hydrologists sampled 150 streams over an 80,000-square-mile area in 10 midwestern states and found triazine herbicides in 55% of them. A sampling later in the spring, after herbicides had been used on the fields, detected herbicides in 90% of the streams. A new enzyme-based immunoassay, which is cheaper and much faster than the usual gas chromatography/mass spectrometry method, was used to identify the presence of the triazine compounds.

When samples collected in the later survey were analyzed further, 34% were found to exceed the proposed Environmental Protection Agency standard for alachlor in drinking water (1.5 ppb), 55% exceeded the standard for atrazine (3.0 ppb), 12% exceeded the standard for cyanazine (9.0 ppb), and 4% exceeded the standard for simazine (35 ppb).

Because some of the sampled streams are drinking water sources, Donald A. Goolsby, USGS water quality specialist for the central U.S., expects to find detectable levels of triazine herbicides in a number of drinking water supplies, too.

About 60% of the pesticides used in the U.S. are applied to crops in the 10 midwestern states where streams were surveyed. USGS plans to do more extensive tests this year.

Most agricultural counties with high groundwater nitrate levels are west of the Mississippi



Note: Environmental Protection Agency standard is 10 mg per L. **Sources:** Department of Agriculture, U.S. Geological Survey

Farmers are also making greater use of manure and forage legumes as a source of nutrients. Many raise livestock to have a source of manure as well as an economical use for hay and forage crops grown in rotations. In humid areas, forage legumes often can provide all or nearly all the nitrogen needed by a crop grown the next year. In semiarid climates, however, such legumes tend to take so much moisture out of the soil that subsequent crop growth is retarded.

A variety of tillage practices are being used in alternative farming to control weeds, pests, erosion, and plant nutrients. There is no single tillage practice that will work on all soils and in all climates. But a tillage system that may have advantages in many different types of soils is ridge tillage as developed by Iowa farmer Richard Thompson.

Ridge tillage itself was first used in China more than 3000 years ago. In modern times, it was used in Nebraska and then in Texas and Arizona for growing cotton. It is a form of reduced tillage that entails planting a crop on the top of ridges, leaving the residue from the previous year's crop largely undisturbed. The soil is not worked ahead of time to prepare a seed bed. On most farms, herbicides are applied in a band over the ridges at the time the seeds are planted.

Ridge-tillage systems are effective in controlling water and wind erosion. If the ridges are laid out on the contour, each ridge can act like a small terrace, and soil that blows off the tops of the ridges tends to collect in the valleys. Erosion is also slowed because crop residues are left on and between the ridges.

Another advantage is the soil on ridges dries out and warms up earlier in the spring so planting can begin earlier. After the crop has come up, ridge tillage also allows for more efficient use of fertilizer because it can be placed along the sides of the rows where it is accessible to crop roots. There is no tilling at the time of planting to disturb weed seeds so ridges help with weed control.

Thompson has modified the conventional ridge-tillage system so that no herbicides are needed. For the past three years, Iowa State's extension service has been conducting trials on Iowa farms that are testing Thompson's method. These trials have not shown any significant differences in yields on ridges with and without herbicides.

Another practice being used in alternative agriculture is to control weeds by shallow cultivation that disturbs soil structure only minimally rather than by using herbicides. Cultivation, like any farming practice, can create more problems than it solves. Done inappropriately on highly erodible cropland, it can add to soil erosion and water quality problems, though it causes much less erosion than fall or spring plowing.

On land growing fruits and vegetables, a number of

Chemical elements essential for growth, development, and maturation of crops

In addition to nitrogen, phosphorus, and potassium, many other elements—calcium, magnesium, sulfur, boron, chlorine, copper, iron, manganese, molybdenum, and zinc—are needed by crops in much smaller quantities. Most of these minor nutrients can be supplied by soil minerals, manure, fertilizers, and plant residues.

Essential chemical element	Form used by crop	Source
Carbon	CO_2	Air
Oxygen	CO_2	Air
Hydrogen	H_2O	Soil water-rainfall, irrigation
Nitrogen	NO_3^-, NH_4^+, N_2	Soil organic matter, animal manures, fertilizers, air (legume crops)
Phosphorus	$H_2PO_4^-$, HPO_4^{2-}	Soil organic matter, soil minerals, fertilizers, animal manures
Potassium	K^+	Soil minerals, animal manures, plant residues, fertilizers
Calcium	Ca^{2+}	Soil minerals, limestone, fertilizers
Magnesium	Mg^{2+}	Soil minerals, dolomitic limestone, fertilizers
Sulfur	SO_4^{2-}, SO_2	Soil organic matter, animal manures, SO_2 in air, fertilizers
Boron	H_3BO_3	Soil minerals, fertilizers
Chlorine	Cl^-	Rainfall, soil, fertilizers, animal manures
Copper	Cu^{2+}	Soil minerals, animal manures, fertilizers
Iron	Fe^{2+}	Soil minerals, fertilizers
Manganese	Mn^{2+}	Soil minerals, fertilizers
Molybdenum	MoO_4^{2-}	Soil minerals, fertilizers
Zinc	Zn^{2+}	Soil minerals, animal manures, fertilizers

Nutrients removed from the soil must eventually be returned if healthy crops are to be grown indefinitely. By combining crop rotations, including legumes (which fix nitrogen from the air), with manure from livestock, farms can be self-sufficient in nitrate and potassium. But over the long run it appears difficult or impossible for them to be self-sufficient in phosphorus.

In addition to the major nutrients it supplies, manure that is treated properly provides organic matter, increases soil's ability to absorb and hold water, and supplies food for microorganisms. Also, manure often releases nitrate at a rate that closely approximates plant needs. Because the nitrate in synthetic fertilizer tends to be more soluble, much of it may leach out of the soil before crops can take full advantage of it, especially if all the fertilizer is applied at one time.

Advocates of alternative farming emphasize the importance of using manure and legumes as major sources of nutrients. But not enough livestock are currently raised in the U.S. to supply crops' nutrient needs. The Department of Agriculture estimates that manure could supply only 15% of the total nitrogen, 10% of the phosphorus, and 24% of the potassium used on all crops now grown in the U.S. However, Alfred M. Blackmer, an agronomist at Iowa State University, believes that these estimates are too low.

Currently, much manure is wasted because it is produced in concentrated amounts in large livestock operations, such as poultry farms and cattle feedlots, many of which are located far from cropland. Instead of a resource, such manure often is an environmental hazard that pollutes water supplies with nitrate.

One underutilized source of nutrients is sewage sludge. Much of the sludge now generated in the U.S. has such high concentrations of heavy metals, however, that it cannot be used indefinitely on cropland. But if all municipalities were to comply with Environmental Protection Agency regulations, most of their sewage sludge could be spread safely on cropland, says Alan B. Rubin, chief of EPA's wastewater solids criteria branch.

alternative farmers are planting grass or another cover crop between rows to control weeds and erosion and to create a habitat for beneficial predator insects. The large vineyards in Arizona and California owned by Steven Pavich & Sons, which produce more than 1% of the grapes in the U.S., have a permanent cover of perennial rye grass between the vines.

Pest control

Alternative agriculture controls pests by maintaining soil fertility, rotating crops, and using integrated pest management, biological controls, and natural products like rotenone. The area of pest control seems to be one of the most complex and diverse, and hence least well understood. Alternative methods developed thus far are highly variable depending on the region of the U.S. In Florida's hot, humid climate, for example, pest pressures are typically very high, so few growers have been able to control insects and diseases without insecticides and fungicides. In the hot, dry climate in California, alternative control techniques are much easier to design.

Some farmers, such as Thompson in Iowa, find that rotating crops, using ridge tillage, and providing a high degree of soil fertility prevent significant yield losses from pests. Even when his soybean fields were surrounded by spider-mite-infested fields in 1988 and other farmers in his area found it necessary to spray for spider mites, Thompson's fields remained largely untouched.

In the Pavich grape vineyards, insects are seldom controlled with insecticides. Usually grapes on conventional California farms are sprayed four to six times a year. Even when the vineyards surrounding the Pavich vineyards in California are heavily infested with spider mites, the Paviches ordinarily spray only a small part of their grapes once a year.

The Paviches believe that careful balance of nutrients in the soil and careful pruning and care of the vines, as

well as growing rye between the rows to provide a habitat for insect predators, help control pests. However, like all other grape growers, the Paviches have to fumigate the ground for nematode control before the vines are planted.

Integrated pest management, developed about 20 years ago and long used by some farmers, especially on cotton, is a pest control strategy based on determining when a pest population is approaching the level at which control is necessary to prevent a decline in net returns.

It does not always reduce pesticide sprayings over what would be done on conventional farms. In fact, in some cases it increases the number. But it does usually decrease the total amount of insecticide used.

There are a number of biological pest controls employed in alternative farming, including release of nonnative natural predator pests, augmentation of domestic natural pest enemies, release of sterilized insect pests, and use of insect pheromones to disrupt their mating.

Many farmers who grow organic vegetables use *Bacillus thuringiensis* (Bt) as an insecticide. It is a species of bacterium found in soil. Each variety of Bt used as an insecticide contains one or more crystalline proteins that kill a specific kind of insect and are harmless to all others and to humans and the environment.

Farmers are developing alternative methods of livestock production to accomplish several goals: eliminate the use of subtherapeutic antibiotics in livestock, eliminate the use of growth hormones, produce animals without investing in large, expensive facilities, and still make a profit.

There is much evidence that high-confinement facilities, such as buildings housing hundreds of hogs, lead to more stress on the animals and hence to more diseases, than would be present if the animals were raised in a less confined environment. Therefore, farmers are designing low- and medium-confinement systems such as pastures with plenty of room for each animal or low-confinement hutch and yard facilities.

A number of farmers are experimenting with what is called intensive rotational grazing, allowing animals to graze a certain pasture only as long as the nutritive value remains high and then moving them onto another field so the first can recover. It requires more labor and more fencing than most pasture systems. For example, Clark BreDahl in southwestern Iowa uses a system of fences and crossfences so that he can turn his cattle and sheep into any of his fields to consume crop residues. Each field or section of field can be grazed for the optimum amount of time.

Economic performance

In general, farmers that have made it through the often difficult transition period when a range of practices are tried out, settle on alternative methods that perform as well or better financially than conventional methods in their area. It is very hard to make detailed comparisons because the performance of diversified, biologically based systems arises from a complex array of interactive factors. Simple input-output analysis is just not feasible. Also, farms using these systems tend to differ greatly, because cropping patterns and practices must be matched to the individual strengths and limitations of each farm's natural resources.

But yields on farms with successfully refined alternative practices are usually just as high or higher than county averages. In animal production, the situation is similar. Animals raised with little or no antibiotics in their feed and in low-confinement facilities seem to be just as productive or more so than those raised with antibiotics in high-confinement operations.

There are some exceptions, however. The organic rice operation owned by Lundberg Family Farms in northern California has yields that are consistently lower than the average for conventional rice production. High-yield methods to provide adequate nitrogen and eliminate herbicides and pesticides in rice production have not been developed.

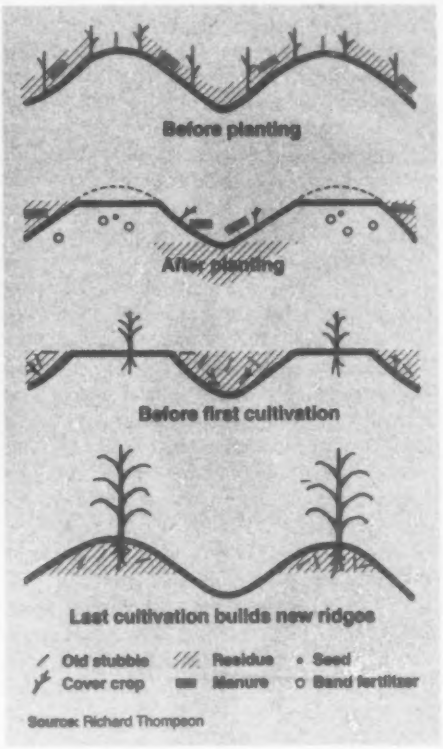
The BreDahl farm illustrates the beneficial effect that low expenses for purchased inputs can have on profits. At 160 acres, it is half the size of the average farm in its county. Detailed financial comparisons have not been made, but local tax experts are convinced the farm ranks in the bottom 25% for the area in gross sales, but in the top 10% in net income.

Currently, it is difficult or impossible for most farmers to move toward alternative farming systems, and in most cases, there has so far been little incentive. Both the federal commodity programs and a lack of information about alternative methods are roadblocks to change. And for many farmers, the conventional methods recommended by extension agents, based on decades of work by agricultural researchers at universities and in industry, have been effective, convenient, and economical.

Under existing law, farmers lose benefits if they rotate crops or respond to market forces by switching to other crops. Crops eligible for price and income supports include feed grains, wheat, cotton, rice, soybeans, and sugar. If farmers' base acres are enrolled for one of these crops, and they reduce their acreage when they rotate to another unenrolled crop, they reduce their potential payments in future years. Also, if the yield of an enrolled commodity crop declines, even for just a year or two, deficiency payments in future years are reduced.

Little information about alternative systems is available to farmers in most states. The information county extension agents supply is largely prescriptive. Except in a few states that provide guidance about integrated pest management, extension agents' handbooks contain mostly chemical methods for controlling weeds and insects, which are listed in tables. For each weed is listed an herbicide (or several herbicides) and its effective application rate. Usually, handbooks contain only one sentence on any other method of managing weeds: "Cultivation can be used to control weeds." The handbooks include similar information for insects—listings of insects and insecticides with application rates. Typically, tillage practices, planting times, crop rotations, allelopathic effects, planting densities, nutrient balance, or other methods that could be used to control weeds or insects are not mentioned.

Dept. of Agriculture photo



Source: Richard Thompson

Ridge tillage often eliminates herbicide use

Ridge tillage, as developed by Iowa farmer Richard Thompson, almost totally eliminates the need for herbicides. First, a planter shaves off 2 to 4 inches of soil in a 6-inch band from the top of ridges remaining from the previous growing season, throwing cover crop, weed seeds, weeds, and soil into the furrows between the ridges. This helps mix manure, which is applied just ahead of the planter (shown in photograph), with the soil and creates a planting strip that is unoxygenated and mostly free of weeds and weed seeds. Three stimulants for weed germination—oxygen, light, and warm temperature—therefore have not been present in the planting strip. Compared with most farms, fast-emerging varieties of corn and soybeans are planted more densely and fertilizer is added. The new plants quickly establish a small shade canopy that provides weed control within the rows. Early weeds are eliminated with a rotary hoe. During the early part of the growing season, crops are cultivated three times. At the last cultivation, the ridges are rebuilt and, in September, a cover crop is planted to control erosion, retain soil nitrogen, and choke out weeds that might germinate later. Thompson claims his method requires more labor than no-till farming with herbicides but less labor than conventional farming with herbicides as practiced on most Iowa farms.

Research needs

Much more research needs to be done before alternative systems are available for all crops in all regions of the U.S. Specialists involved in agricultural research say the major thrust of research in the area must focus on how different organisms interact in overall farming systems rather than on narrow isolated problems or the impacts of specific inputs, as in the past. Interdisciplinary research is needed to study the interactions between various components of a farming system and the biological and ecological foundations of farming systems that are both profitable in the near-term and sustainable over many years.

Specialists also agree not enough is known about existing alternative techniques to determine whether they are truly sustainable in the long run. They stress that on-farm research is important for developing alternative systems. It involves the farmer so it tends to address questions that he or she needs to have answered. Often in the past, a new agricultural technique appeared to fail simply because the person taking care of the research plots at the experimental station didn't know how to manage that technique. If farmers with highly developed skills are taking care of the plots, this is less likely to happen. Also, when research is carried out on a farm, the results are more accessible and perhaps more credible to other farmers.

The National Soil Tilth Laboratory in Ames, Iowa, is being organized to study overall farming systems. "What the soil tilth lab will be doing is looking at interactions between chemical, physical, and biological systems at all levels," says Jerry L. Hatfield, director of the lab. "Others looked at these individually. We are setting up our research so it is multidisciplinary at the outset."

Some areas of alternative agriculture that especially need more research are low-cost low-confinement facilities for livestock, less toxic replacements for fungicides or practices that will eliminate or reduce the need for fungicides, and development of systems of growing vegetables and fruits in hot, humid areas without

Alternative agriculture on small versus large farms

"A long-term transformation is underway in American agriculture from small-scale, broad-based family farming to large-scale industrial farming," says Marty Strange, program director of the Center for Rural Affairs, an advocacy group in Walthill, Neb., for low-income farmers and other rural people.

The total number of farms in the U.S. dropped from about 5.9 million in 1945 to 2.2 million in 1985. Now, the largest 4% produce about half the food, and 400 superfarms produce a sixth of the nation's food—more than all the farms in Iowa, Illinois, and Florida together.

With the decline in the number of farms has come the depopulation of rural communities. For example, rural counties in Iowa, Kansas, North Dakota, South Dakota, Minnesota, and Nebraska have lost on average 6% of their population since 1969, while the total population of these states has risen 8%. North Dakota has had to initiate a triage policy, letting some communities die while giving economic aid to others. State officials in North Dakota say there isn't enough money to maintain services in all the communities, and there is little hope of attracting new businesses to all of them, so they try to save a few that seem to offer the most hope of sustaining a viable economy.

Some applaud the changes that are taking place. It is good that fewer people can produce more food than ever before, they say. And even if it is not good, it is inevitable. Food can be produced most efficiently and cheaply on very large farms, they allege.

But others, like Chuck Hassebrook, policy analyst at the Center for Rural Affairs, view the situation as neither positive nor inevitable. As the farms in an area become larger and larger, the communities in those areas become less desirable, Hassebrook says. "A substantial body of research indicates that farm communities in which land is widely held are more prosperous than those with concentrated land ownership in nearly every respect, including lower poverty rates and a greater variety and larger number of local businesses, churches, schools, community organizations, and public services," he explains.

Dean MacCannell of the University of California, Davis, has studied the relationship between farm size and economic and social structure of rural communities. "Communities that are surrounded by farms that are larger than can be operated by a family unit have a few wealthy elites, a majority of poor laborers, and virtually no middle class. The absence of a middle class at the community level has a serious negative effect on both the quality and quantity of social and commercial services, public educa-

heavy use of pesticides or with use of less toxic pesticides.

Farm bill proposals

A number of the legislative proposals for the 1990 farm bill will, if enacted, benefit alternative agriculture. Nearly all of those addressing agricultural commodity programs aim to give the farmer more flexibility in deciding which crops to plant. All sides in the current debate over the farm bill, even those who disparage alternative agriculture, believe the existing farm program rules are too restrictive and reward farmers for practices that make little sense agronomically or environmentally.

The Administration proposal announced Feb. 6 by Agriculture Secretary Clayton K. Yeutter would allow farmers to plant alternative crops without losing government benefits.

Basically, the Administration bill would use what it calls "positive incentives" to reduce soil erosion, groundwater contamination, and other environmental problems and it emphasizes the need for more research and education.

Another proposal, also announced Feb. 6, by a coalition of environmental groups and supported at least in part by several Congressmen, takes more of a regulatory and activistic approach. The most extreme proposed regulation would require that farmers keep records of pesticide and nutrient use and develop plans to reduce their use. In areas where water quality is a problem, farmers would be required to develop plans by 1995 to reduce the use of potential pollutants and to implement these plans by 2000.

Yeutter is opposed to this regulation. He believes that it will antagonize farmers.

To reward farmers who adopt sustainable practices, the coalition supports incentives for rotations, for planting cover crops, and for adopting practices that protect water quality. It also wants food grading standards changed to eliminate the emphasis on cosmetic appearance of fruits and vegetables. A large fraction of pesticides are now used solely to ensure that foods will measure up cosmetically, even when processed into sauces or juices. In addition, the coalition asks that strong uniform federal standards be set up for organic farming to promote its use. Currently, 15 states have regulations—each different—governing organic farming.

The Sustainable Agriculture Working Group, a network of midwestern alternative agriculture and environmental organizations, has pro-

C&EN staff photo

Carpenter: NRC report not a prescription for every farm

tion, and local governments," MacCannell says. He describes such communities as neofeudal and structurally similar to those in the Third World.

Most U.S. government agricultural policies have helped large farms more than small and mid-size ones, Strange says. Therefore, if a conscious effort is made to change these policies to aid smaller farms or to at least create a level playing field, the trend toward larger and larger farms can be reversed, he argues. Even the agricultural research projects that the Department of Agriculture chooses to fund are a form of social planning, he adds. Some projects, like the development of an apple-picking robot costing $160,000, can help only very large farms. Therefore, choosing projects that are relevant only to large farms is one more force aiding their growth and taking research money from projects that might benefit smaller farms.

Robert E. Barrow, Master (head) of the National Grange, holds similar views. He says that the very commodity policies, tax laws, trade, and foreign and fiscal policies that the Grange supported for many years have created "an agricultural production machine that has consumed farmers. . . . Our emphasis has been on production rather than people. Yet, there is compelling evidence that, from the perspective of rural development, it is time to reexamine the questions of farm structure."

To counteract the trend toward larger farms, eight midwestern states have passed laws that make it illegal for corporations to purchase any more farmland.

Hassebrook believes alternative farming methods could help small and mid-size farms by reducing their need for purchased supplies and thus enabling more of them to stay in business. This could help reverse the trend toward larger and larger farms, he says.

Hassebrook also thinks that sustainable systems are more likely to be used and to succeed on mid-size or small farms because alternative farming requires highly developed management skills.

Charles M. Benbrook, executive director of the Board on Agriculture at the National Research Council, agrees that if alternative agriculture is to succeed on a broad scale, the trend toward larger and larger farms will have to be reversed, though he acknowledges that alternative methods have been used on some very large farms.

Because of this reciprocal relationship between smaller farms and alternative agriculture, a number of groups who are interested in helping family farms and strengthening rural communities are also interested in promoting alternative agriculture.

posed legislation that would remove existing penalties in commodity programs and reform federal farm programs so that they would reward farmers for preserving and improving soil and water resources. The working group's approach is broader than that of the environmental coalition. The coalition's proposals focus on specific areas of the U.S. with acute pollution problems from farming practices, by paying farmers who are causing particular problems to change. The working group's proposals would reward careful stewardship of the land across the board, including those farmers who have been practicing alternative agriculture all along. They also would reorient publicly funded agricultural research toward alternative methods.

Reactions

For the most part, chemical company spokesmen express a favorable attitude toward alternative agriculture. They recognize that some serious problems are associated with conventional agriculture. "In most cases if we are really going to protect soil and water, the move to sustainable methods will be a very positive thing," says Will D. Carpenter, vice president for technology at Monsanto Agricultural. "Those of us who have been in agricultural research readily accept that we can improve and modify a number of agricultural practices in terms of fertilizers and pesticides. There is no doubt that that should be done, must be done, and will be done."

However, he points out that a whole range of people, from members of Congress to environmental organizations to the media, are misinterpreting the NRC report. They are looking at it as a set of prescriptions for all farms, when, in fact, much more research needs to be done before all farmers can adopt alternative methods.

He also says that some people look at the report and say, " 'What we really need is a lot more cultivation and a lot less use of herbicides.' But there is virtual agreement that cultivation [for weed control] has probably been the single biggest cause of soil erosion in North America."

Carpenter believes that the movement toward alternative agriculture will enhance Monsanto's sales. Monsanto is using biotechnology to develop pest- and virus-resistant crops, he says. These will eliminate the need for pesticides on some crops.

Monsanto is also using biotechnology to develop a soybean plant that is resistant to its Roundup herbicide (glyphosate), allowing farmers to use "one of the most environmentally friendly pesticides on corn and soybeans."

However, emphasizing protection of the environment in developing new pesticides has a downside, Carpenter says. "The pesticides that get on the market are going to be a lot better than the ones that are on the market now. But because of the high cost of development, you are not going to see pesticides developed for the small-acreage crops, and virtually all of our food crops fit into that category. So the very place where you would like to have new [safe] products will be the places that will be the last to get them."

John F. McCarthy, vice president for science and regulatory affairs at the National Agricultural Chemicals Association, expects that the movement toward alternative agriculture will cause "some reduced use of agricultural chemicals in some areas." But he doesn't think

Richard Thompson photo

Young pigs on this Iowa farm are raised in small units so the animals can get sunlight and exercise.

there will be major cutbacks. "We think there will still be a need to manage weeds, disease, and insects by the judicious use of chemicals," he says.

He believes industry will respond by developing materials that are active against weeds, diseases, and insects in very small amounts and so are less likely to get into groundwater or leave residues.

However, Frost & Sullivan Inc., a market research firm in New York City, predicts that growth in pesticide sales will level off after 1990, partly because more pesticide products will be restricted or banned.

Spokesmen for the fertilizer industry are taking a more negative approach. Harold F. Reetz Jr., director for the west central states of the Potash & Phosphate Institute, calls the NRC report "unscientific."

He doubts that alternative systems could work very well on a wide scale: "We have 100 years of research that has studied various systems, studied the low-input alternative systems along the way, and they've always fallen out as not being efficient and economically viable, and that's the reason we're not using them."

Basically, he believes that conventional agriculture itself is sustainable. "Some people seem to be on a witch-hunt to disprove what we have been doing—to say that the results of long-term research and extension programs and farmer practice are suddenly not good anymore. I've not seen any solid evidence that would tell me that reducing fertilizers and pesticides would solve either our economic or environmental problems."

In general, he doesn't believe farmers could significantly reduce the use of synthetic fertilizers by rotating crops or using other alternative methods and still produce good yields. "Whenever you remove crops from the farms, you're removing nutrients that have to be replaced," he says. He regards legumes and manure as unrealiable sources of nitrogen. Nitrogen from manure and legumes "is most likely released when the crop can't use it and thus it would be wasted and become a potential environmental hazard," he says. Therefore, fertilizer sales will not be affected by a move toward alternative methods, he says, unless farmers temporarily start depleting the soils. "Well-fertilized crops produce deeper roots and leave more crop residue to help soil erosion and better utilize nutrients deeper in the root zone," he adds.

Spokesmen for crop growers' associations fear that the NRC report on alternative agriculture will lead to a public push for stronger regulation of pesticides and fertilizers, so that farmers will lose some important weapons against pests. Already, they point out, many older useful pesticides for minor crops have not been available simply because of the high cost of reregistration, especially for products with expired patents and small sales volume.

"There will be a number of pesticides banned," says Dan W. Ragsdale, director of research for the National Corn Growers Association. "I am not totally convinced that it's necessary to do it. A lot of the good compounds are old ones, and no company is willing to invest money to defend some of these."

Most farmers also oppose extreme regulation against pesticides, such as total bans on many of them. Even farmers who currently use no pesticides want to have some available in case of an emergency. But the fear of immediate large-scale bans is probably unrealistic because such drastic measures have not even been proposed by environmental groups.

In the long run, the success or failure of alternative agriculture will probably depend on what farmers themselves decide to do. It will not depend on the fears of the public, or perhaps even very much on regulation. Alternative farming methods originated with farmers and the main force promoting these methods will probably remain with farmers as long as they continue to experiment and find methods that work.

But no matter how enthusiastic farmers are about alternative methods, broad change is not likely to come quickly without changes in federal farm policies and R&D priorities. The enthusiasm of farmers already using such methods is always tempered by admonitions to other farmers like: "Don't jump in too fast. Try it gradually, experiment on a small part of your acreage at first to see if you can manage it. Yields are often lower for the first few years when you try these new methods. Every farm is different and you must know how to manage yours very carefully, or you will fail." □

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